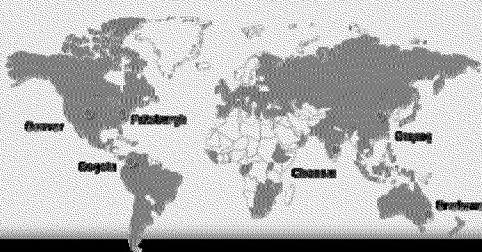


# **Permanent Solutions to Restore Upper Animas River Water Quality**

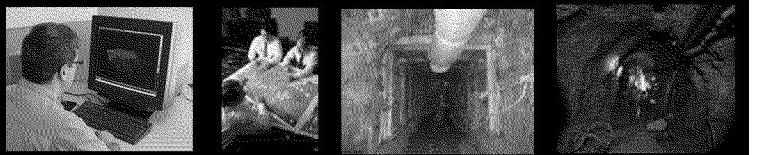


**presented to**  
**Key Influencers**  
**On Behalf of**  
**Animas River**

**by**  
**Greg Sparks, P.E.**  
Managing Director - Metals  
John T. Boyd Company



**John T. Boyd Company**  
Mining, geological, and technical consultants  
Pittsburgh - Denver - Australia – China - Colombia - India



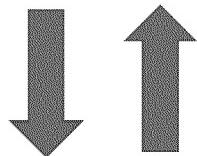


John T. Boyd Company

# Animas River Water Quality Solutions

## Purpose of Presentation

**Concepts for Permanent Restoration of  
Upper Animas Water Quality (legacy mines)**



**Explore Strategies to Make it a Reality**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Introduction of GBS

Managing Director - Metals Group

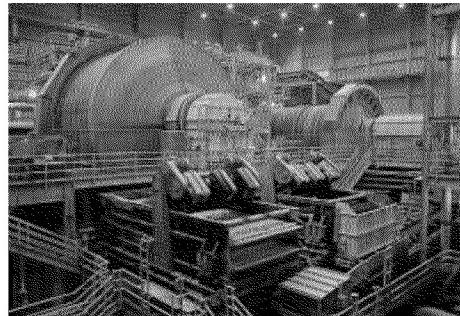
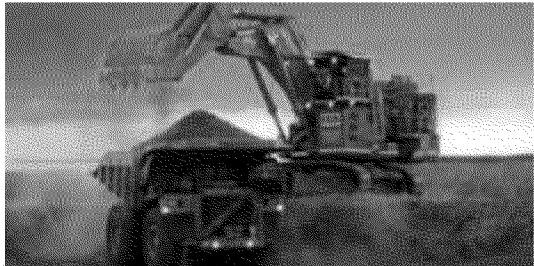
P.E. Mining Engr., Q.P., C.P. (42 years experience)

International Exposure (23 countries plus US)

Analyzed, Designed, Built, and Operated mines and plants to 50 million tpy Ore Production (s&ug)

Many years experience in Silverton District (s&ug)

Practical/Solutions Oriented



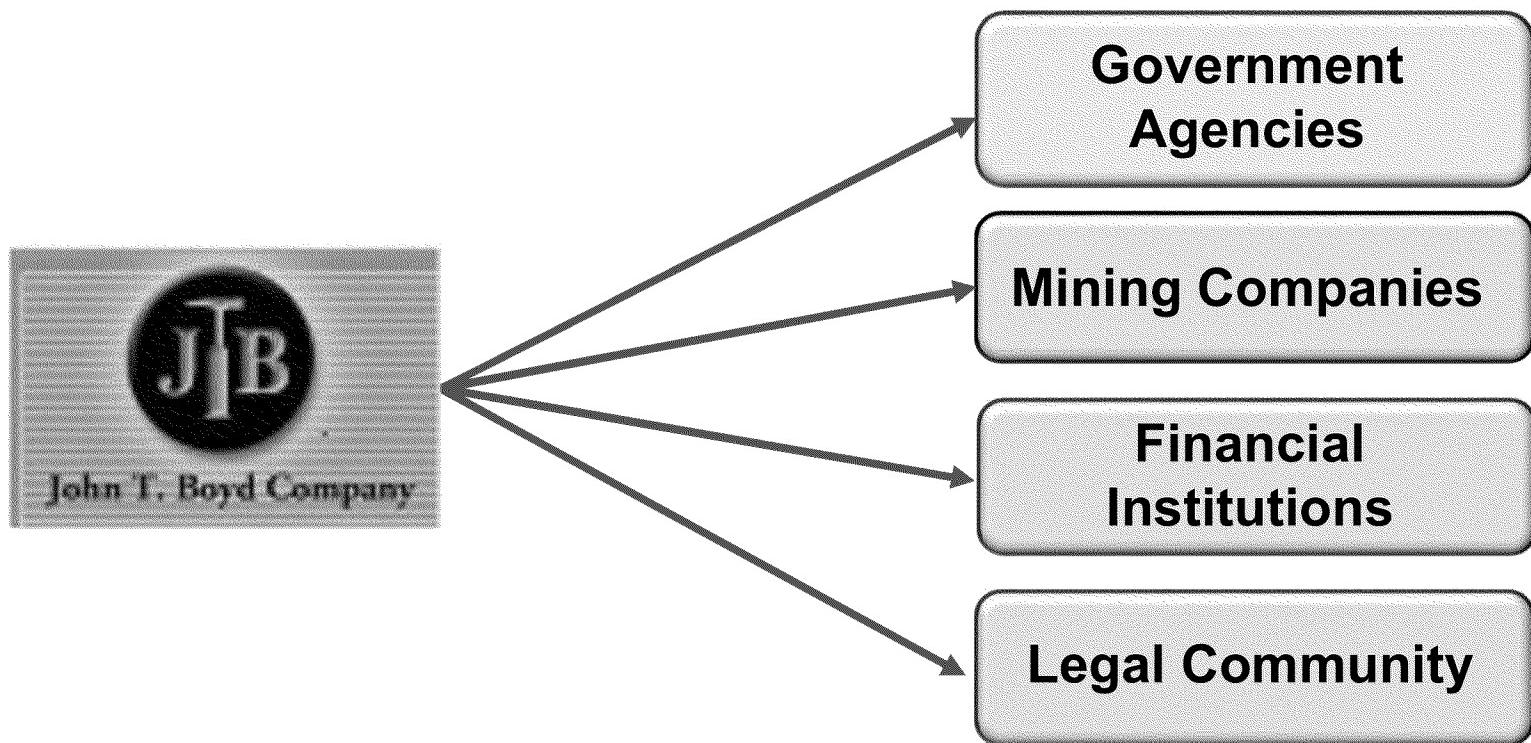
Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## John T. Boyd Company Technical Consultants Since 1943



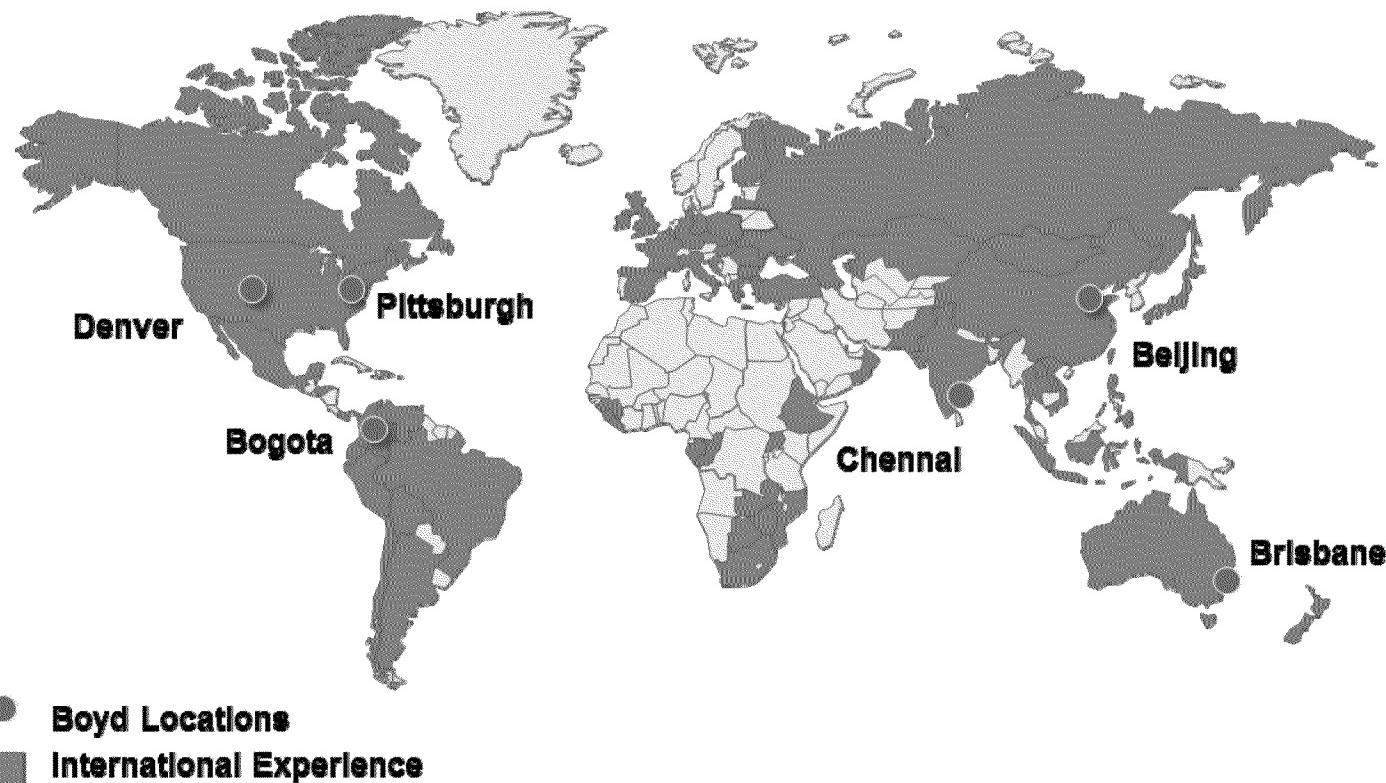
Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## John T. Boyd Company Experience in Over 50 Countries



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Role of Cement Creek A Right Bank Tributary to the Upper Animas River

### Primary Source of Pollutants in Upper Animas River

- Acid water
- Dissolved heavy metals
- High turbidity



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Cement Creek

How Did it Get This Way?

**Intense sulfide mineralization coming into contact with oxygenated water.**

- Mineralization from Silverton Caldera (ancient volcano)
- Involves surface and underground hydrologic system
- Network of faults due to tectonic stresses from collapsing caldera provides conduits for oxygenated water to enter the groundwater system and percolated downward to escape to through seeps and springs, and through mine portals.

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Cement Creek

Is Historic Mining Responsible?

**Partially, but it has always existed to some degree.**

- Evidence collected by the USGS confirms that it has been a problem to some degree for at least 4,500 years.
- Historic mining activities have certainly exacerbated the problem
  - Introduced more oxygenated water to the underground hydrologic regime
  - Dramatically increased available reactive sulfide surfaces
  - Adits have provided additional drainage to the creek

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Hurdles to Plan Development



- Cost (Initial and on-going)**
- Technology hurdles**
- Perpetual active treatment**
- Stakeholder divisions**
- Who is Responsible**
- Public/private issues**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Strategy for Success

### Must

- Rely on Proven Technology**
- Be Cost-Effective and Affordable**
- Begin With Active Transitioning to Passive Treatment**
- Be Drainage-Wide (Cement Cr) in Scope**
- Not Impair Private Interests**
- Be Collaborative**
- Involve Cost Sharing**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The BOYD Concept

- Collect Cement Cr Drainage Just Above Animas R. Confluence for Temporary Active Treatment
- Maximize Use of Gravity to Save \$\$\$
- Limestone as Principal Treatment Agent (well proven)
- Use Locally Available Limestone to Save \$\$\$
- Build In Redundancy to Avoid Upsets (spills)
- “Inoculate” Reactive Sulfide Surfaces Underground to Make Stable
- Once Stable, Transition to Open Flow Passive Treatment

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Upper Cement Cr. Drainage



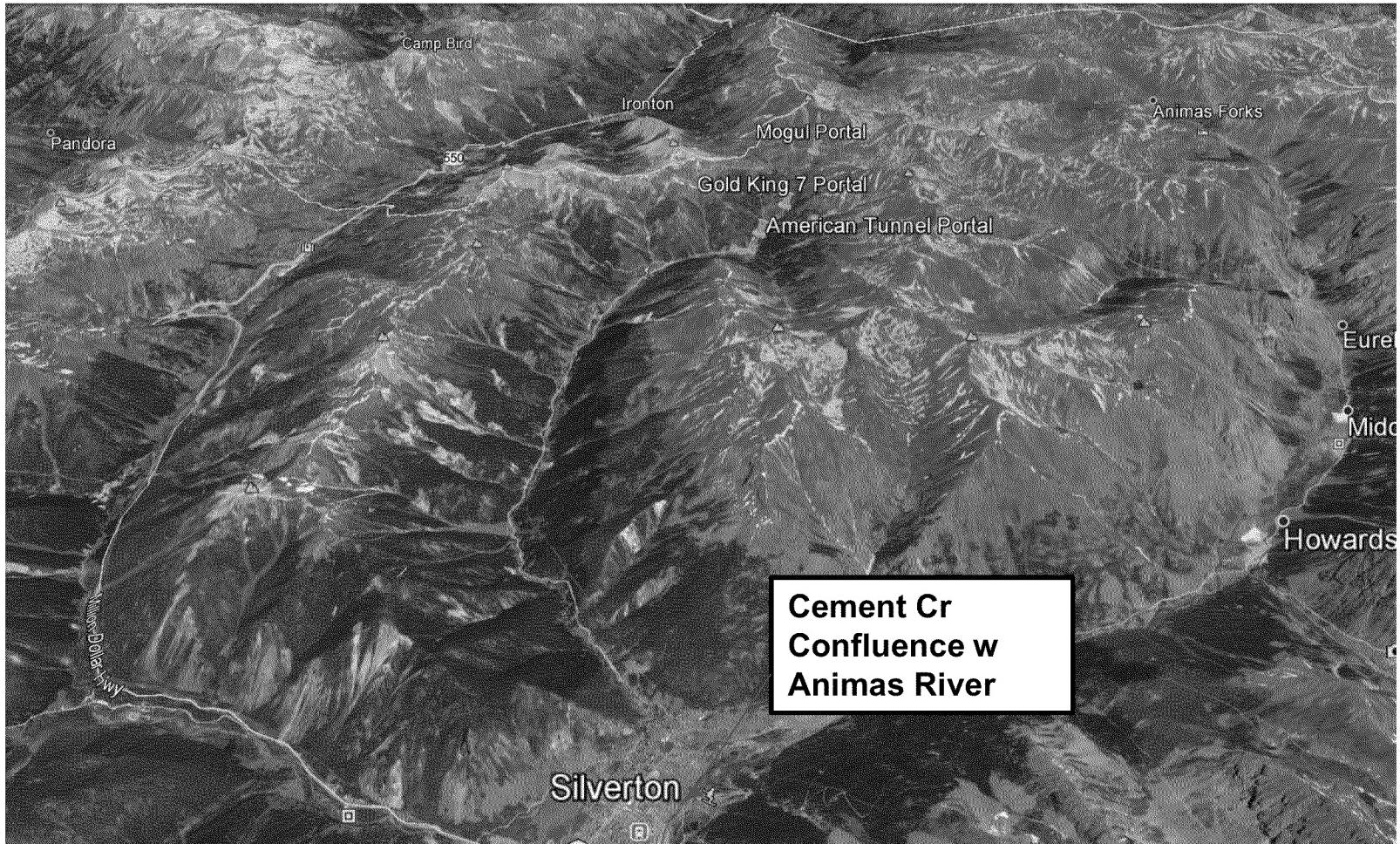
Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Overview Cement Cr. Drainage



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Cement Cr Joining Animas R. During Gold King Spill



Photo by Ray Dileo/Silverton Standard

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Locally Available Limestone For Period of Active Treatment

**USGS Has Mapped Limestone Deposit Within  
2 miles of Silverton**

- Ouray Limestone 12 – 15 meters thick
- Leadville Limestone 60 meters thick
- Units are in direct contact one above the other

**LS Units Located Southwest of Silverton at Basal  
Elevation of 9,450ft – Silverton at Approximately  
8,980ft**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Cost Difference for LS For Period of Active Treatment

### Nearest Commercial Limestone

- Salida, CO – 248 mi – fob Silverton cost \$45 - \$60/ton
- Delta, CO – 107 mi – fob Silverton cost \$40 - \$55/ton  
(costs similar due to Red Mtn Pass and smaller loads)

### Local Limestone Production prelim estimate - \$10/ton

- Direct production cost including capital amortization
- No trucking required

**No Firm Estimate Yet for Annual Tonnage, but likely to be in the range of 20,000 – 25,000 tons per year minimum**

**Order of Magnitude Savings - \$700k - \$1 million/yr**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Local LS Production Plan Small Scale Underground Quarry

- Shallow decline from surface
- Portal below from valley floor
- Install crushing equipment u/g
- Ore pass from LS horizon to portal elevation



No weather impacts on u/g quarry

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Water Treatment Plant Underground Installation

- Locate u/g plant beneath LS deposit**
- Portal driven from valley floor Southwest of Silverton**
- Install diversion and overflow near mouth of Cement Creek** (divert base flow [6cfs/3,000gpm] to treatment plant w flood overflow directly to Animas River)
- Pipe flow for treatment to u/g treatment facility by gravity** (1.7 miles / 94 ft drop)

Cheaper to pipe water downhill than haul gravel up



John T. Boyd Company

# Animas River Water Quality Solutions

## Conceptual Site Plan Diversion, Pipeline, and U/G Treatment Plant



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Design Technology

- Very tall counter-current reactor column(s)**
- Contaminated water flows by gravity from bottom of column to decant over the top**
- Prepared LS is fed from the top to slowly settle through the water column raising pH and collecting metal hydroxides as the particles travel downward**
- Metal hydroxide sludge settles to a collection cone at the bottom**
- Sludge feeds to a belt filter through a rotary valve**

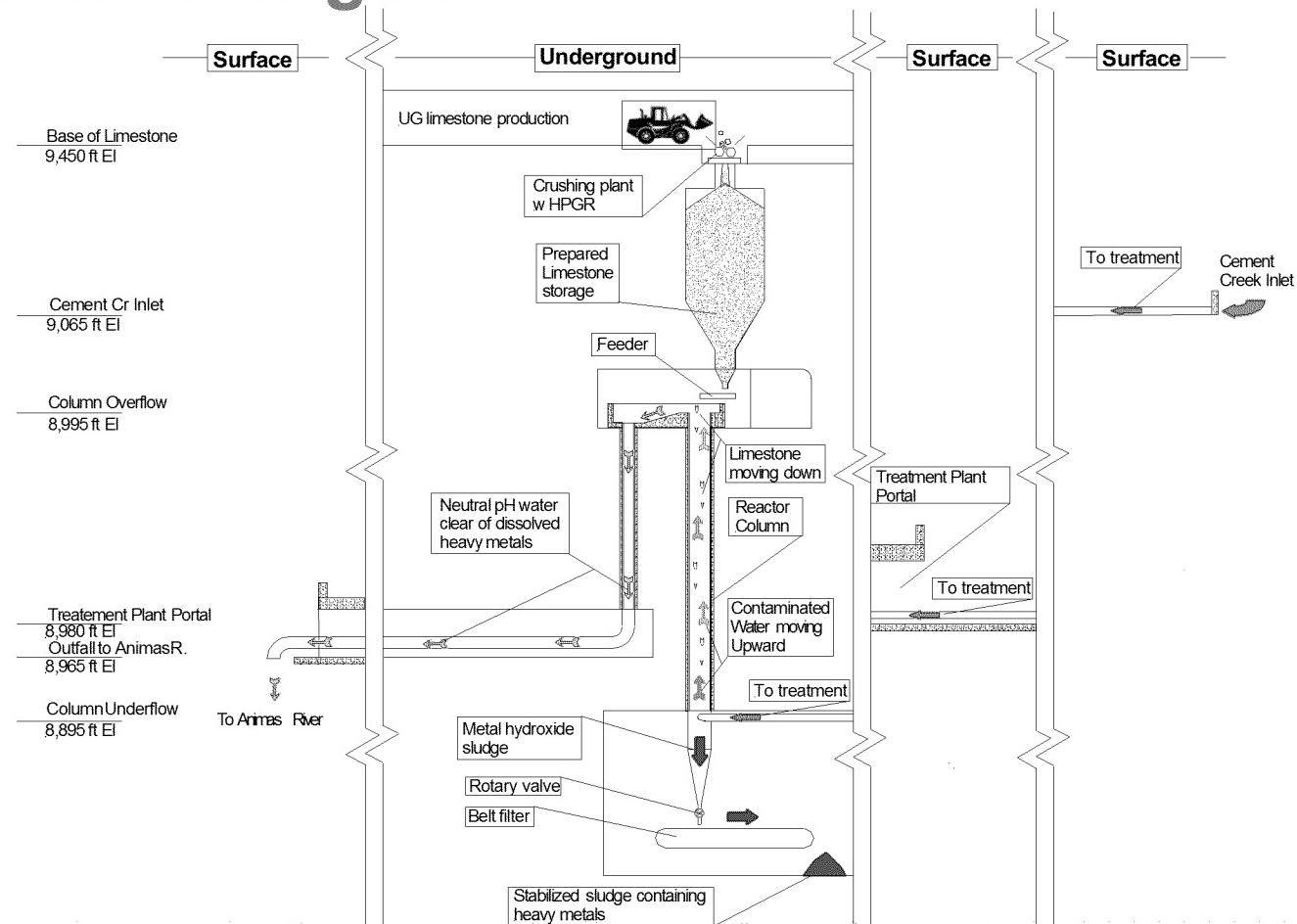
Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant General Arrangement



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Discussion

- Use HPGR to achieve uniform particle size (+/- 2mm) and to create micro-fractures in LS particles**
- May need limited NaOH for fine pH adjustment to achieve levels necessary for Zn precipitation**
- Will include redundant reactor circuit to provide back-up for upsets and maintenance**
- May need second stage reactor in series for polishing**
- Alternative polishing may include Zeolyte filtration**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Sludge Handling

- Settled sludge concentrated in collector cone to be metered through rotary valve**
- Sludge to be dewatered utilizing a belt filter**
- Sludge “cake” discharged from belt filter to be collected for permanent storage**
- Filtrate water to be re-injected into reactor feed**
- Sludge to stored on site**



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Permanent Sludge Storage Alternatives

### Storage in excavated limestone caverns

- Would require elevation to cavern level (vertical conveyor)
- Most secure as buffered environment
- No additional stabilization required

### Storage in surface cell near portal

- Would likely require portland cement stabilization
- Less secure
- Surface footprint required
- Comparative costs need to be studied



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Major Advantages to BOYD Plan

- Treatment of entire base flow of Cement Creek (+/- 6 cfs or 3,000 gpm)
  - Captures all flows from any source in drainage
  - Provides for flood overflow when surface dilution water is greatest, thus maintaining water quality in Animas River
- Harnesses gravity to avoid pumping costs (capex, opex, and maintenance)
- Locally available Limestone (cost savings estimate at \$700k to \$1million/yr)
- Gravity delivery of Limestone to treatment plant, i.e., no trucking

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Active Treatment Plant Major Advantages to BOYD Plan – (cont.)

- Use of rock mass (u/g plant) to preclude need for building envelope and elimination of structural elements for plant
- Ability to practicably utilize very long reactor columns to achieve optimum reaction times
- Relatively little mechanical equipment to be purchased and maintained
- No weather related issues with underground system
- High efficacy, cost-effective treatment to permit treatment of entire base flow from Cement Creek

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Phase I Active Treatment Plant BOYD Plan



Prepared for Animas River Key Influencers – October 2015



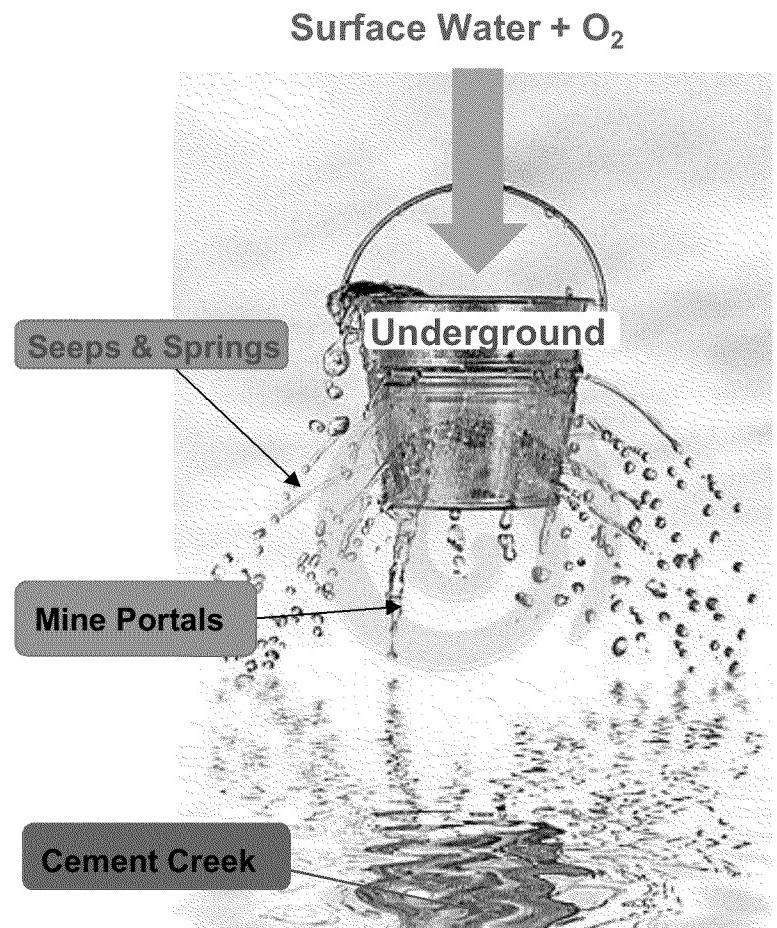
John T. Boyd Company

# Animas River Water Quality Solutions

## Phase II Permanent Reduction of AMD KEY ISSUES

### Attempts to seal portals have not been successful to date

- Plan was to reduce oxygen level in static water to prevent sulfide reaction
- Problem has been the u/g hydro regime has too many leaks
- Result is continuous turnover w fresh oxygen rich water from surface continuing to react and leak producing AMD and draining into Cement Creek



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Phase II “Inoculation” Alternative to Leaking Bucket With Active Treatment System On Entire Cement Creek Drainage in Place ...

- Construct temporary seals (bulkheads) in all know mine portals
  - Install large diameter dump valves through bulkheads
  - Install pressure gages to determine hydrostatic head
- Close valves and build water to maximum equilibrium head
- Identify, map, and monitor seeps and springs (flow and quality)
- Drill multiple injection wells into underground openings distributed over hydrologic regime (maybe a couple of dozen?)
- Inject massive doses of buffering agent (NaOH) plus compressed air into wells to oxidize mineral surfaces and render non-reactive
- Alternatively, or perhaps in combination with, inject bio-oxidants for the same purpose

Prepared for Animas River Key Influencers – October 2015

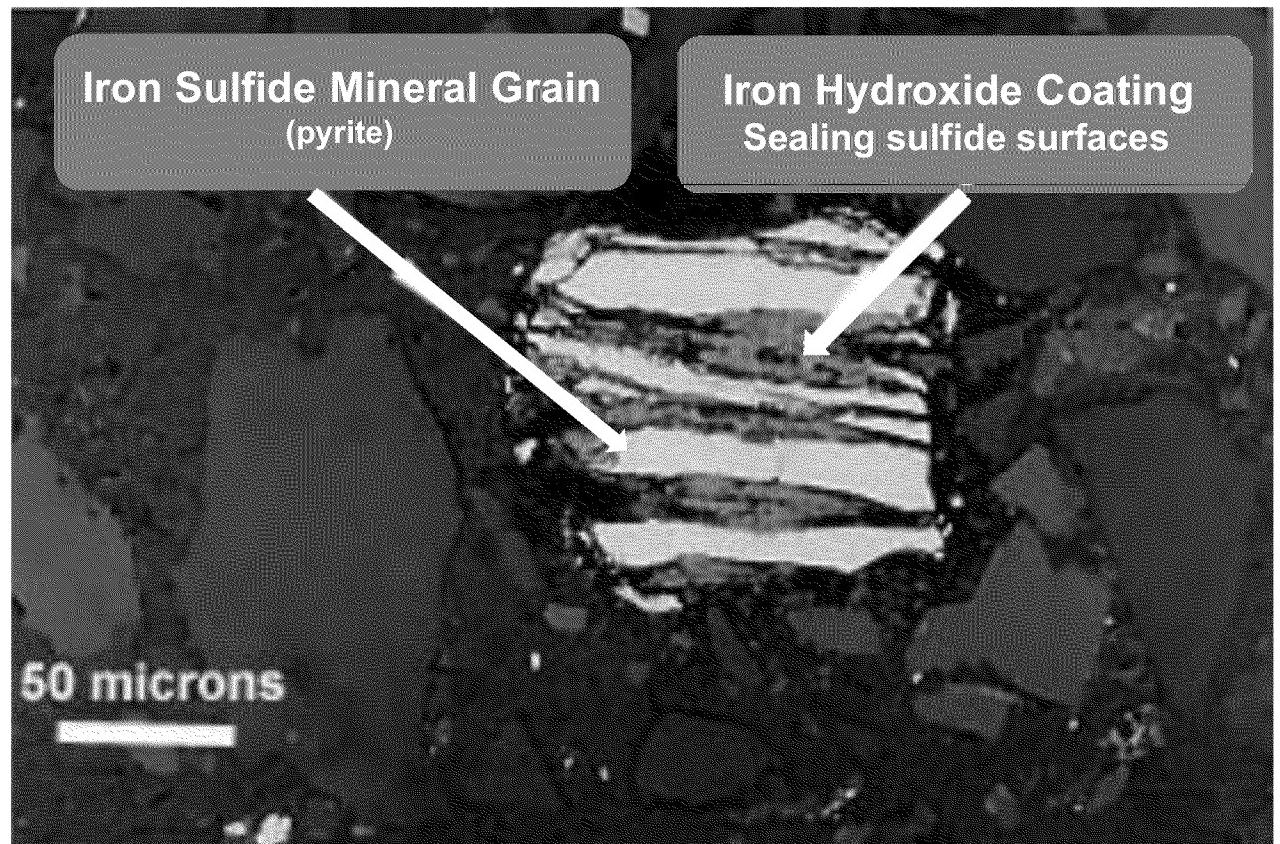


John T. Boyd Company

# Animas River Water Quality Solutions

## Phase II “Inoculation” How it Works

Note iron hydroxide coating surface of sulfide surfaces rendering them unavailable for further acid generating potential



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Phase II “Inoculation”

### Why it Will Work

- Water in entire hydro regime below the static water level will be rendered strongly basic in the presence of oxygen (NaOH and compressed air injection) to oxidize surfaces
- Inevitable leakage will bring treated water in contact with surfaces in fractures including micro-cracks
- Hydro system may require multiple cycles to provide thorough inoculation potentially involving
  - Differentially raising and lowering impounded water behind various bulkheads
  - Cycling the entire hydrologic system
- Sulfides existing above static head equilibrium will not be exposed to inoculation, but should eventually seal over as well

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Phase III Transition to Passive Gradual and With Active System On-Line

- Water behind each bulkhead would be drawn down in sequence beginning with uppermost elevation to maintain uniform static head
  - Continuous monitoring to confirm efficacy
  - Re-inoculation if water quality not meeting requirements
  - Flow rate gradually increasing to max capacity of active treatment plant
- Cover remaining acid generating dumps and divert surface flows if any
- Install crushed Limestone drains from portals and major seeps
- Install crushed Limestone in the lower portion of Cement Creek channel
- Shutdown active treatment plant**



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Passive Treatment On-going

Well Not Quite ... Must Monitor and Maintain Fail-Safes

- On-going monitoring
  - At each point source (quality and flow)
  - Cement Creek contribution (quality and flow)
- Immediately close valve on any bulkhead experiencing an upset
- Re-inoculate as necessary, e.g. a fall of ground exposing fresh sulfide surfaces
- Maintain active treatment plant in ready-state to deal with upsets
- As hydrologic system stabilizes monitoring frequency can be reduced to annual.



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward

Must Involve Agencies and Government at Federal, State & Local Levels Working Together with Stakeholders

- Agree on logical steps to move forward**
  
- Identify key roles**
  - Planning
  - Execution
  
- Find funding source(s)**
  - Feasibility
  - Active treatment period
  - On-going passive system monitoring



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward Project Phase – Feasibility Study

- Definitive data collection
- Component trade-off studies
- Proof of key concepts (testing)
- Final scoping/project definition
  - Phase I –Active treatment
  - Phase II – Inoculation
  - Phase III – Transition to passive system
- Capital Cost estimating (capex)
- Operating Cost estimating (opex)
- Project Schedule

**Order of Magnitude Cost Estimate - \$2.0 – 3.0 million**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward

### Project Phase – Active Plant Construction

- Develop and equip u/g limestone production facility
- Construct u/g water treatment plant
  - Portal and u/g excavation
  - Install mechanical equipment
- Install pipeline from Cement Creek to facility
- Construct Cement Creek diversion structure

**Capex Cost Guestimate - \$12.0 – 15.0 million**

**Opex Cost Guestimate - \$1.0 – 2.0 million/yr**

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward

### Project Phase – Inoculation of u/g system

- Construct bulkheads w valves and instrumentation
- Drill and equip injection wells
- Inject buffering/bio-oxidation solution (plus compressed air)
- Staged drawdown of hydrostatic head
- Monitoring

**Capex Cost Guestimate - \$5.0 – 7.0 million**

**Opex Cost Guestimate - \$1.5 – 2.5 million/yr\***

\* Includes on-going active plant operation

Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward Order of Magnitude Costs

Total Capex \$19 - \$25 million

Total Opex \$8.5 – \$14.5 million

(assumes 1 yr active plant only plus 5yrs to complete inoculation)

**Grand Total \$27.5 – \$39.5 million**  
**To Permanently Restore Water Quality**  
**In the Upper Animas River Spread over**  
**Approximately 7 years time**

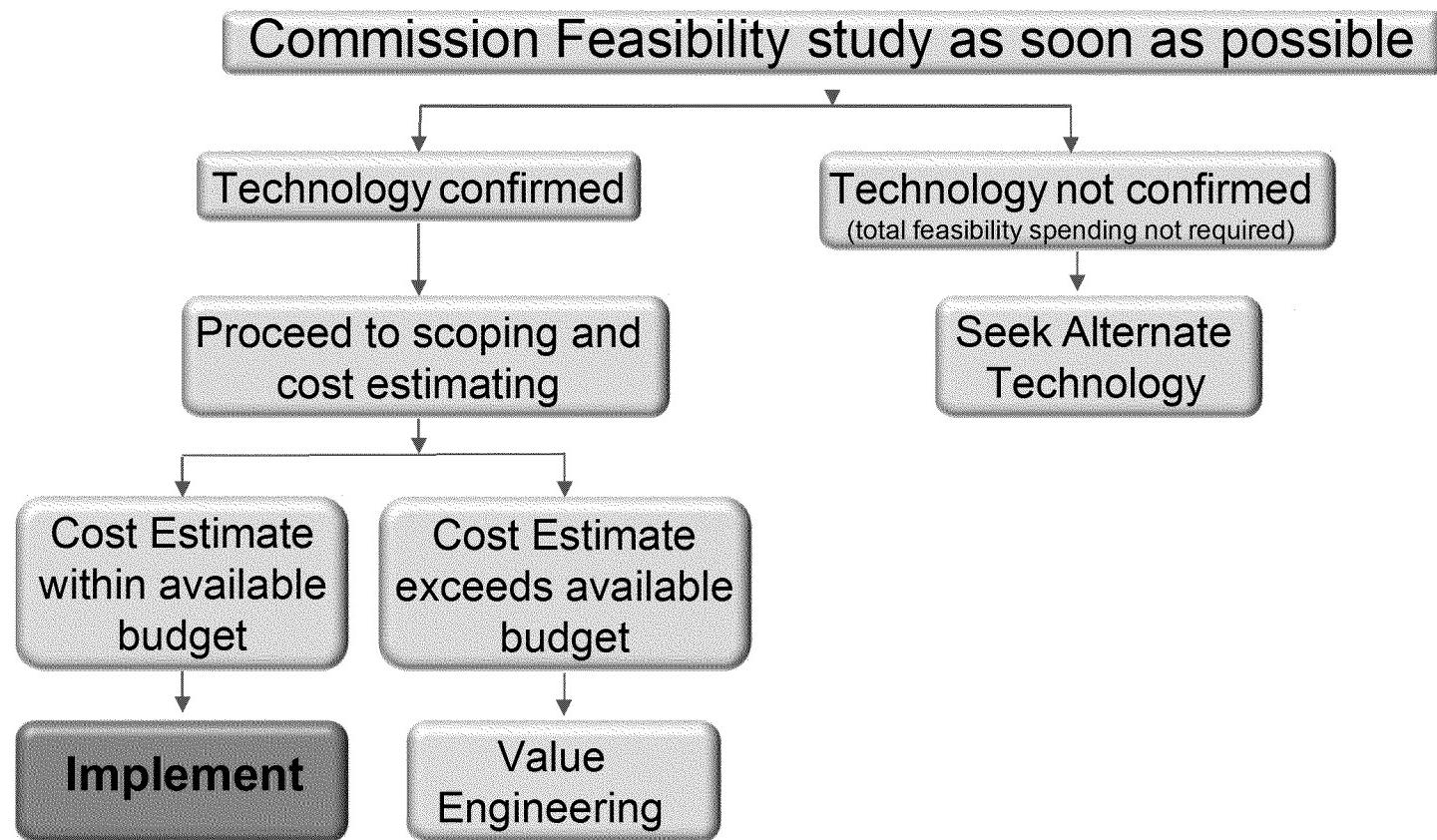
Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## The Way Forward Key Recommendation and Decision Points



Prepared for Animas River Key Influencers – October 2015



John T. Boyd Company

# Animas River Water Quality Solutions

## Conclusion

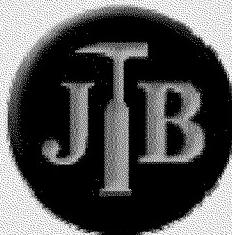
### At Last!

- BOYD believes it has developed a logical, workable, and cost-effective action plan to permanently meet target water quality standards in the upper Animas River**
  
- Naturally, we would like to be involved**

Ω Ω Ω

Prepared for Animas River Key Influencers – October 2015

# Thank You



**Greg Sparks, P.E.**  
**MD - Metals**

John T. Boyd Company

4000 Town Center Boulevard  
Suite 300  
Canonsburg, PA 15317  
United States  
724.873.4400 Ph

[www.jtboyd.com](http://www.jtboyd.com)

**John T. Boyd Company**  
mining and geological consultants

Pittsburgh - Denver - Australia – China – Colombia - India

